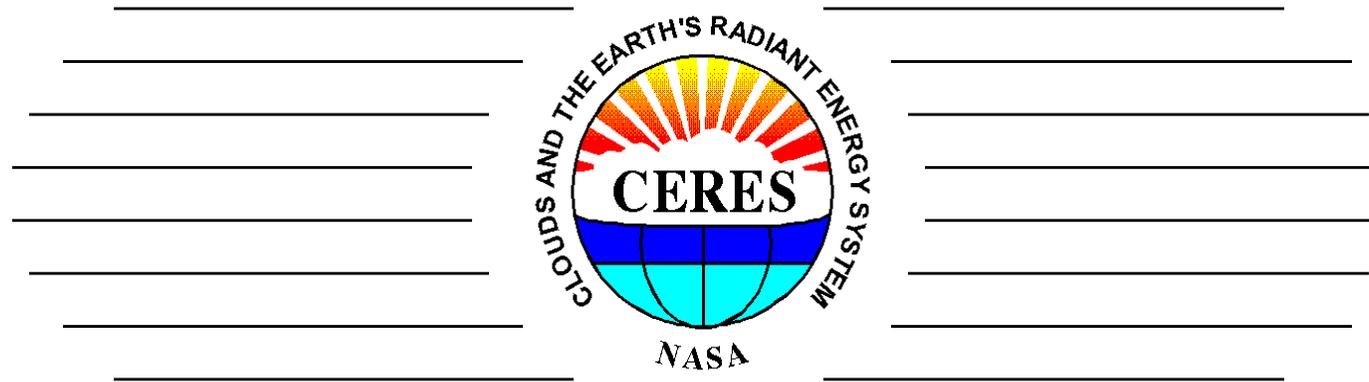


CERES Instrument Status Flight Models 1-6 (FM1-FM6)



Mohan Shankar

CERES Instrument Working Group

CERES Spring Science Team Meeting
April 26, 2022

CERES Instrument Working Group



CERES Instrument Working Group

PS: Kory Priestley
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Instrument Operations

- B. Mike Tafazoli -
Janet Daniels
Christopher Brown
Cian Branco
Carol Kelly
Ethan Ames

Data Management

- Denise Cooper -
- Dale Walikainen -
A. Thomas Grepotiis
Dianne Snyder

Cal/Val

-Susan Thomas-
Hyung Lee
Nathaniel Smith
Nitchie Smith
Z. Peter Szewczyk
Robert Wilson



CERES Instrument Status Summary

- **All CERES instruments continue to demonstrate stable performance.**
 - NOAA-20/FM6 instrument continues to perform nominally.
 - SNPP/FM5 is currently operating in full biaxial mode.
 - *No evidence of deviation of instrument performance since transitioning to biaxial mode.*
 - Terra/FM2, Aqua/FM4 currently operating in Biaxial mode.
 - Validations show that all instruments are performing consistently.
- **Data products**
 - NOAA-20/FM6 Edition 1 gains have been delivered through Mar 2022.
 - S-NPP/FM5 Edition 2 gains and SRFs have been delivered through Mar 2022.
 - Terra and Aqua instruments' Edition 4 gains and SRFs have been delivered through Feb 2022.



CERES Instrument Operations Summary

- **Operational Modes:**
 - Terra/FM1, Aqua/FM3, NOAA-20/FM6 are operating in the Crosstrack mode.
 - Terra/FM2 operating in biaxial mode since November 1, 2021.
 - Aqua/FM4 is operating in biaxial mode since July 14, 2021.
 - S-NPP/FM5 is operating in biaxial mode since Oct 1, 2019; *Full* biaxial mode since Mar 23, 2020.
- **Aqua successfully conducted a reset of the Solid-State Recorder (SSR) on March 23, 2022, to fix an anomaly (occurred on Feb 22, 2022).**
 - CERES instruments were SAFED during the reset and then restored to normal operations.
- **Aqua had a spacecraft anomaly, likely due to solar weather event, on March 31, 2022.**
 - Aqua/CERES instruments were SAFED and then resumed normal operations on April 15, 2022.
- **Inter-comparison operations planned in summer 2022:**
 - Terra/FM1 – S-NPP/FM5: May 1 – Jul 31, 2022
 - Terra/FM1 – NOAA-20/FM6: May 1 – Jul 31, 2022
 - Terra/FM1 – Aqua/FM3: Jun 1 – 30, 2022
 - Terra/FM2 – GERB: Jun 1 – 30, 2022



NOAA-20/FM6 Instrument Status

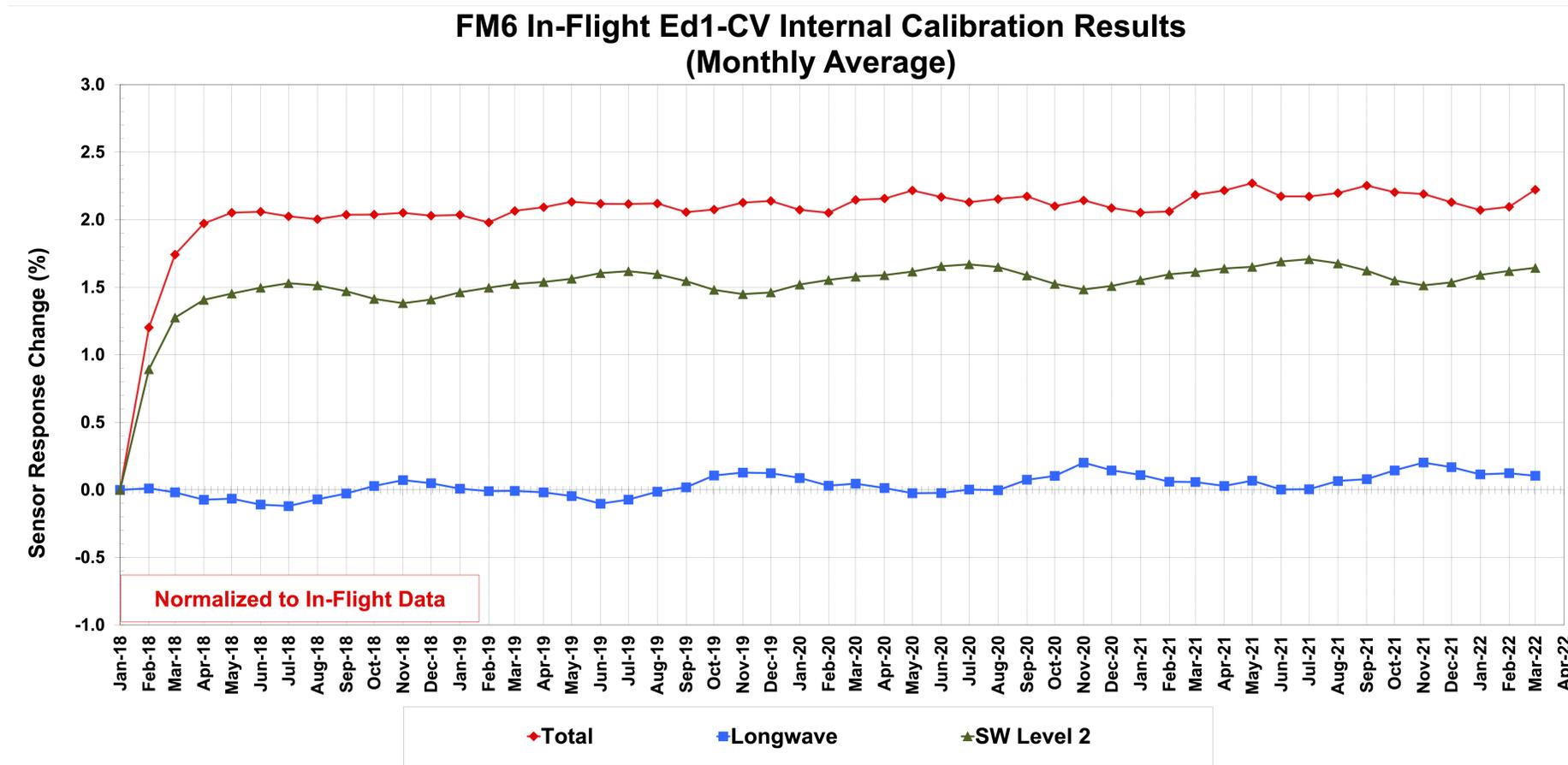


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FM6 Internal Calibration

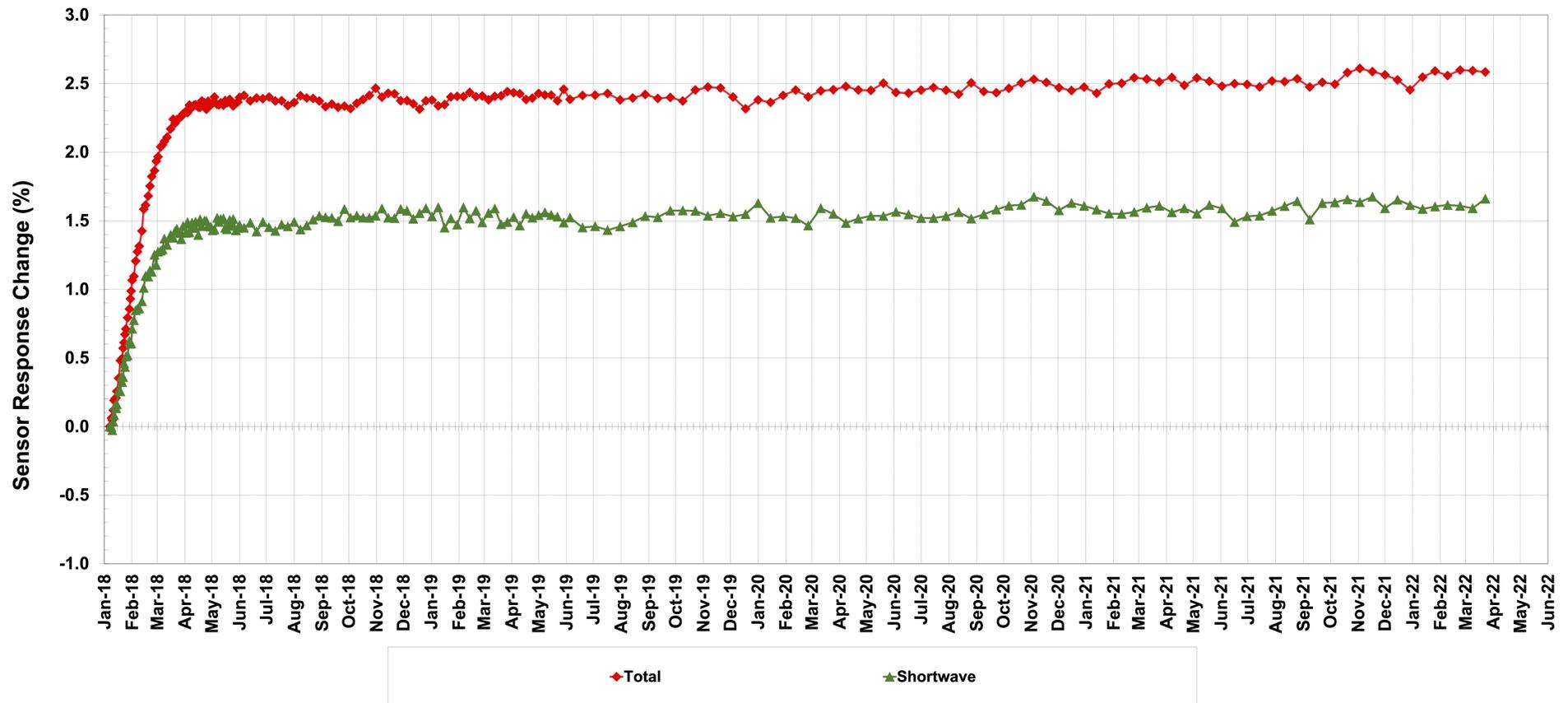
- For SW and TOT channels, the responses to the on-board sources (SWICS lamp and Blackbodies) continue to be quite stable after the initial rise of ~1.5% (SW) and ~2% (TOT) since start of mission.
- LW Channel (calibrated using blackbody) continues to show very little change.



FM6 Solar Calibration

- Response of the SW and TOT channels while viewing the MAM that is illuminated by the sun.
- After the initial rise of $\sim 1.5\%$ for SW, and $\sim 2.3\%$ for TOT, the response is quite stable.

FM6 Solar Calibration



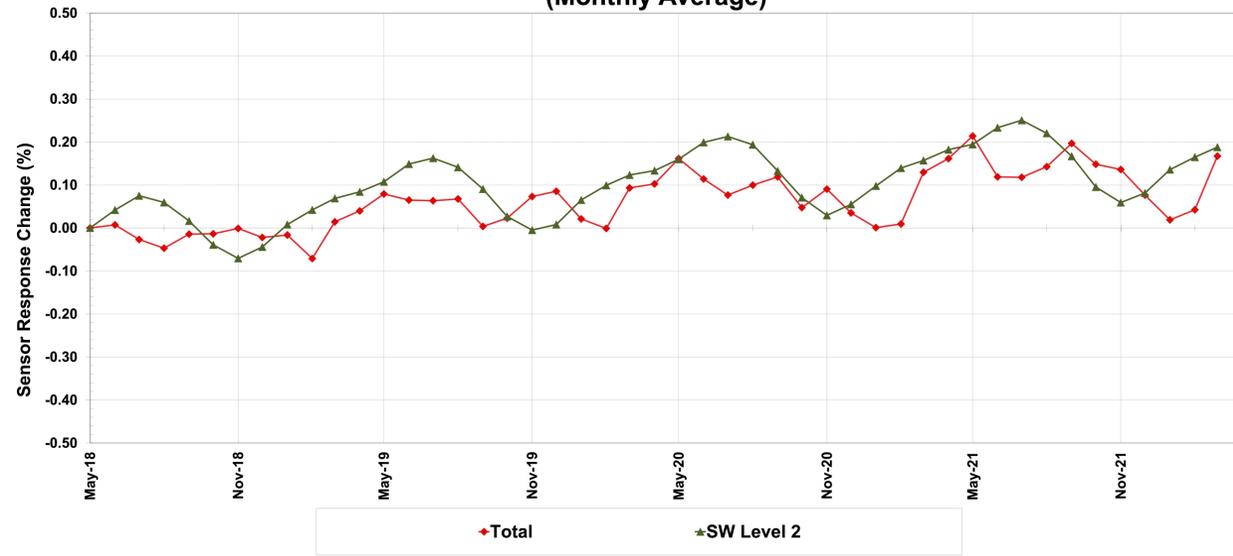
CERES Instrument Working Group



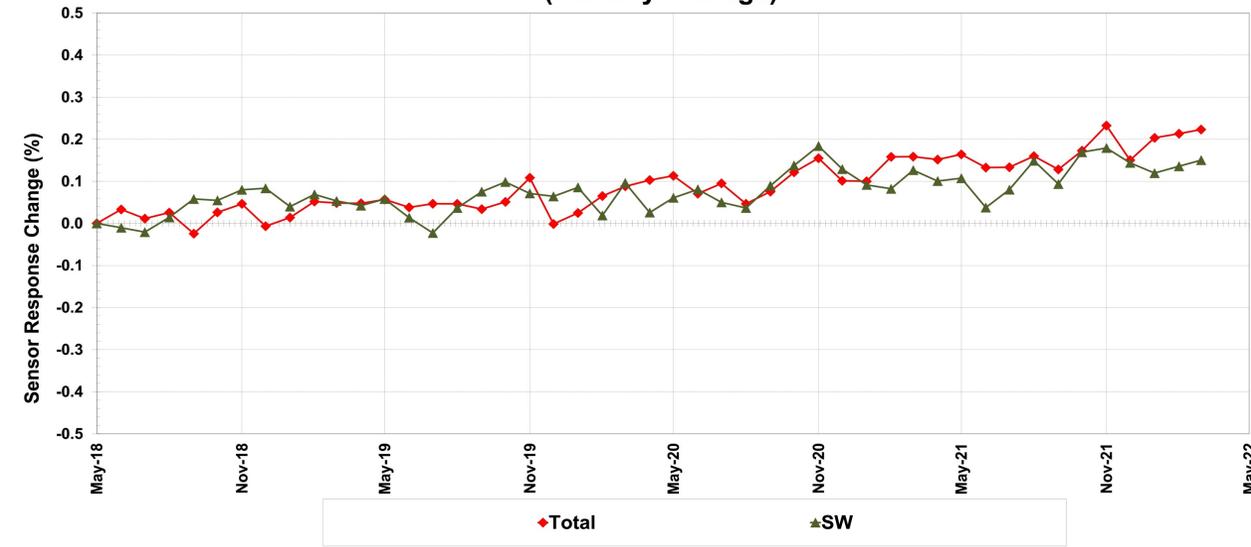
FM6 Calibration- Internal and Solar Cal Since May 2018

FM6 Internal and solar calibration results consistently show about 0.2% change since May 2018, demonstrating that the MAM is very stable.

FM6 In-Flight Ed1-CV Internal Calibration Results
(Monthly Average)



FM6 Solar Calibration
(Monthly Average)



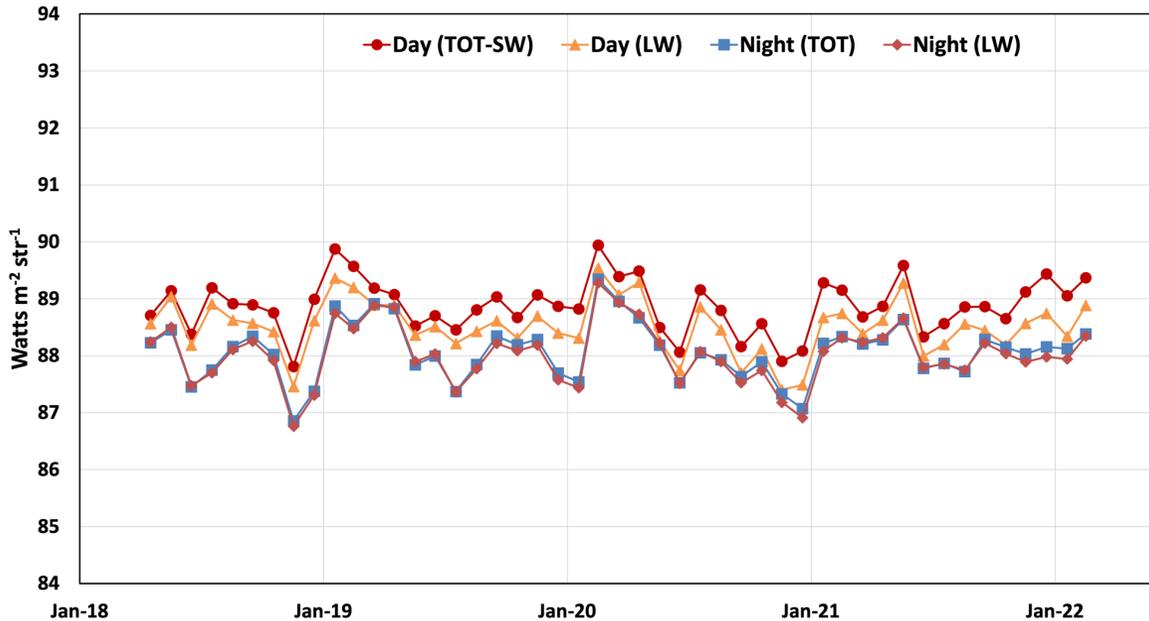
Validation – Tropical Mean

- Average of the ES-8 Nadir radiances over Tropical ocean (20⁰N-20⁰S) scenes under All-sky conditions.
- Two sets of TM Day-Night Differences (DN) are calculated:
 - TOT and SW sensors
 $DN = TM_D(TOT-SW) - TM_N(TOT)$
 - LW sensor
 $DN = TM_D(LW) - TM_N(LW)$
- Difference in the two DN values highlight any inconsistencies in the shortwave regions of the sensors.

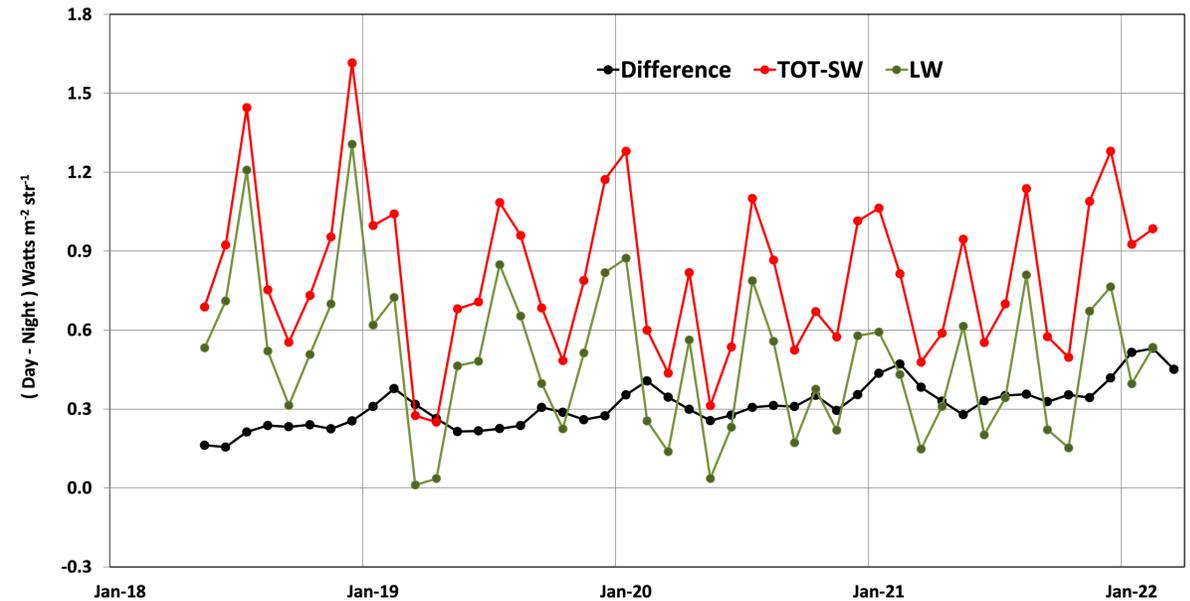


Validation- FM6 Tropical mean Day-Night

FM6 Edition1 Nadir Tropical Mean



FM6 Edition1 Nadir TM Day-Night Difference

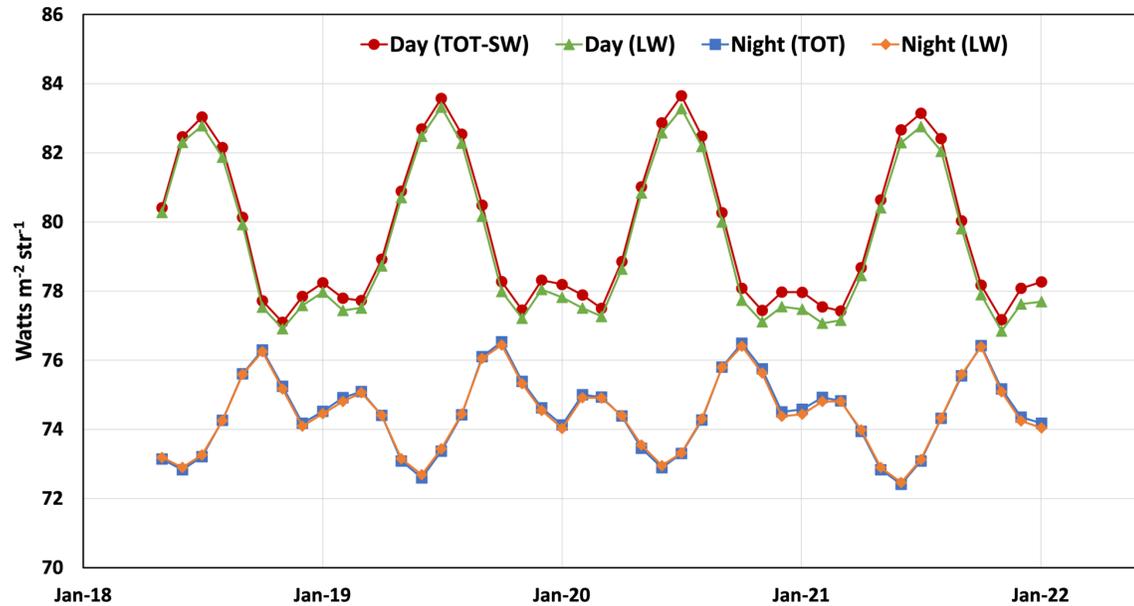


FM6 3-channel Consistency check- Global Day-Night Differences

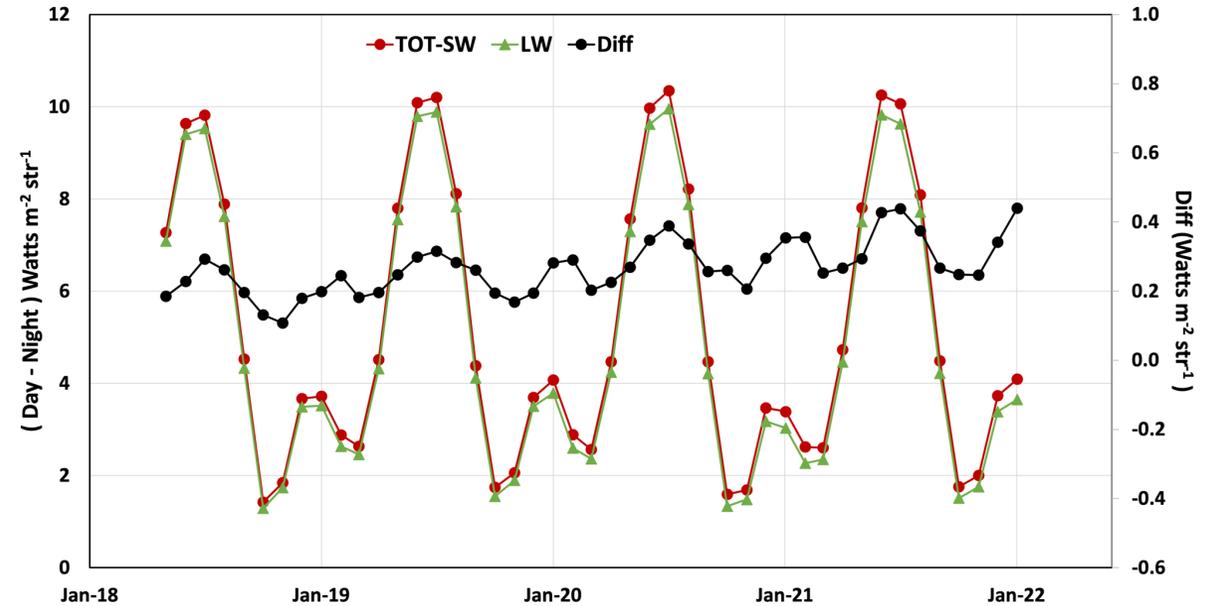
May 2018 - Jan 2022

Edition 1 ES-8, Global, All-sky, Nadir Radiance

FM6 Edition 1 Global Mean



Day-Night Difference



Aqua/NOAA-20 Intercomparisons

- The orbital geometries for Aqua and NOAA-20 are such that orbital overlaps occur every ~64 hours.
- Obtain spatially and temporally matched observations during every crossover.
- No special operations are conducted to match viewing geometries; Both instruments continue operating in cross-track mode.
- Use matching criteria to subset the data:
 - SZA, VZA difference < 2.0°
 - RAZ difference < 5°
 - Distance between centroid of footprints < **7 km**
- Obtain monthly all-sky SW reflectance and daytime LW radiance differences using the matched footprints.

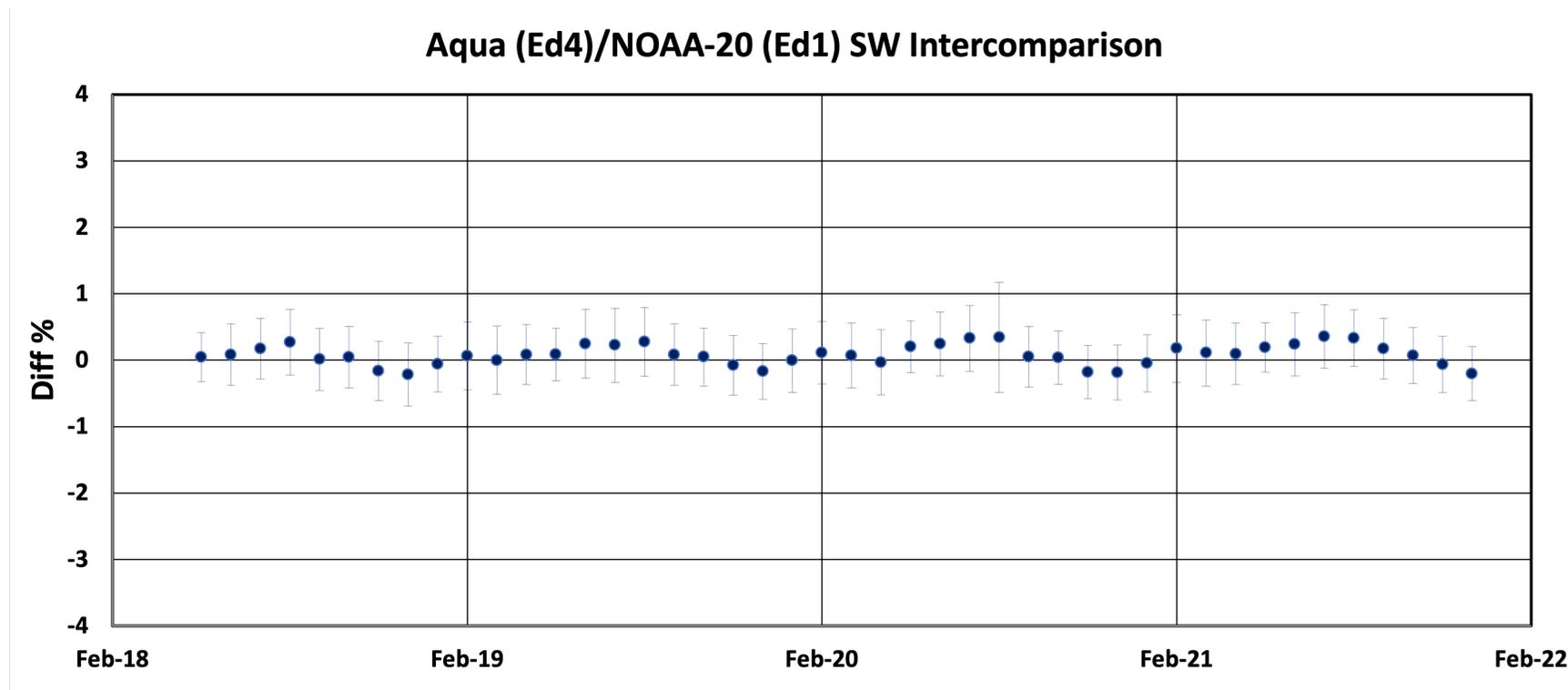


FM3/FM6 SW All-sky Inter-comparisons: May 2018- Dec 2021

Difference of Reflectance:
FM3-FM6 %, 95% CI

$$Reflectance = \frac{SW_{rad} * \pi}{F * \cos(SZA)} \quad F=1361 \text{ W/m}^2$$

Aqua (Ed4)/NOAA-20 (Ed1) SW Intercomparison



Data:
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM6-VIIRS_Edition1B

Radiometric scaling of FM6 to FM3 done in May 2018.

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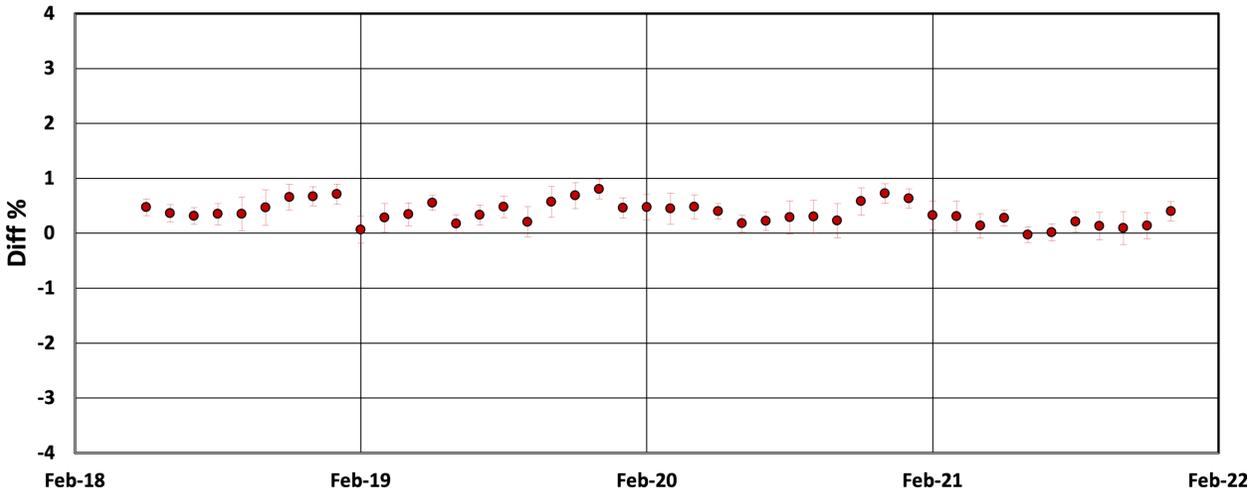


FM3/FM6 LW All-sky Inter-comparisons: May 2018-Dec 2021

**Difference of Daytime Radiance:
FM3-FM6 %, 95% CI**

Daytime LW for FM6 obtained from TOT-SW

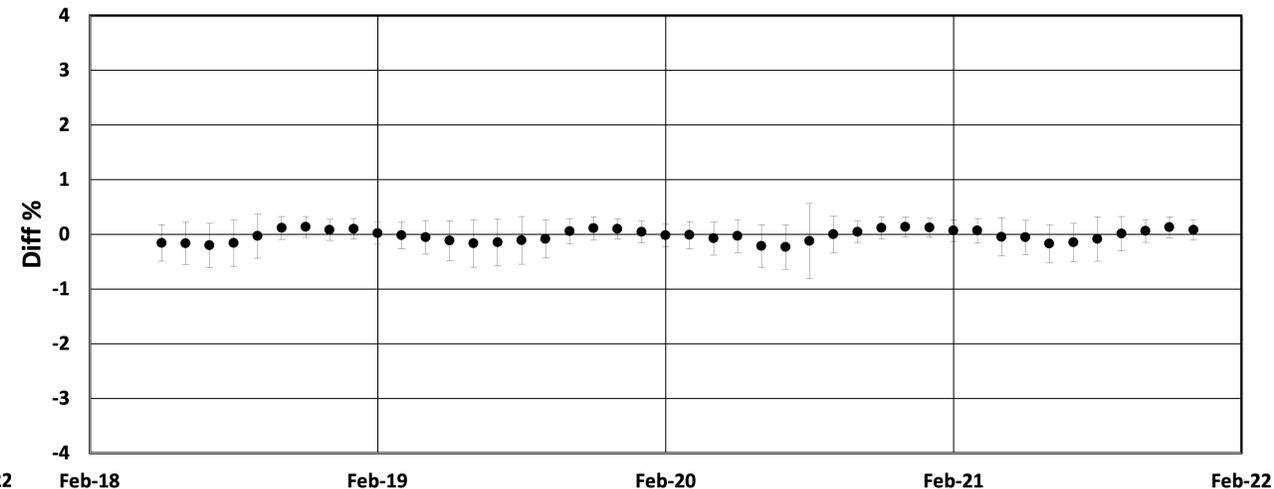
Aqua (Ed4)/NOAA-20 (Ed1) Daytime LW Intercomparison



**Difference of Nighttime Radiance:
FM3-FM6 %, 95% CI**

Nighttime LW for FM6 obtained from TOT

Aqua (Ed4)/NOAA-20 (Ed1) Nighttime LW Intercomparison



Radiometric scaling of FM6 to FM3 done in May 2018.

Data:
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM6-VIIRS_Edition1B



S-NPP/FM5 Instrument Status



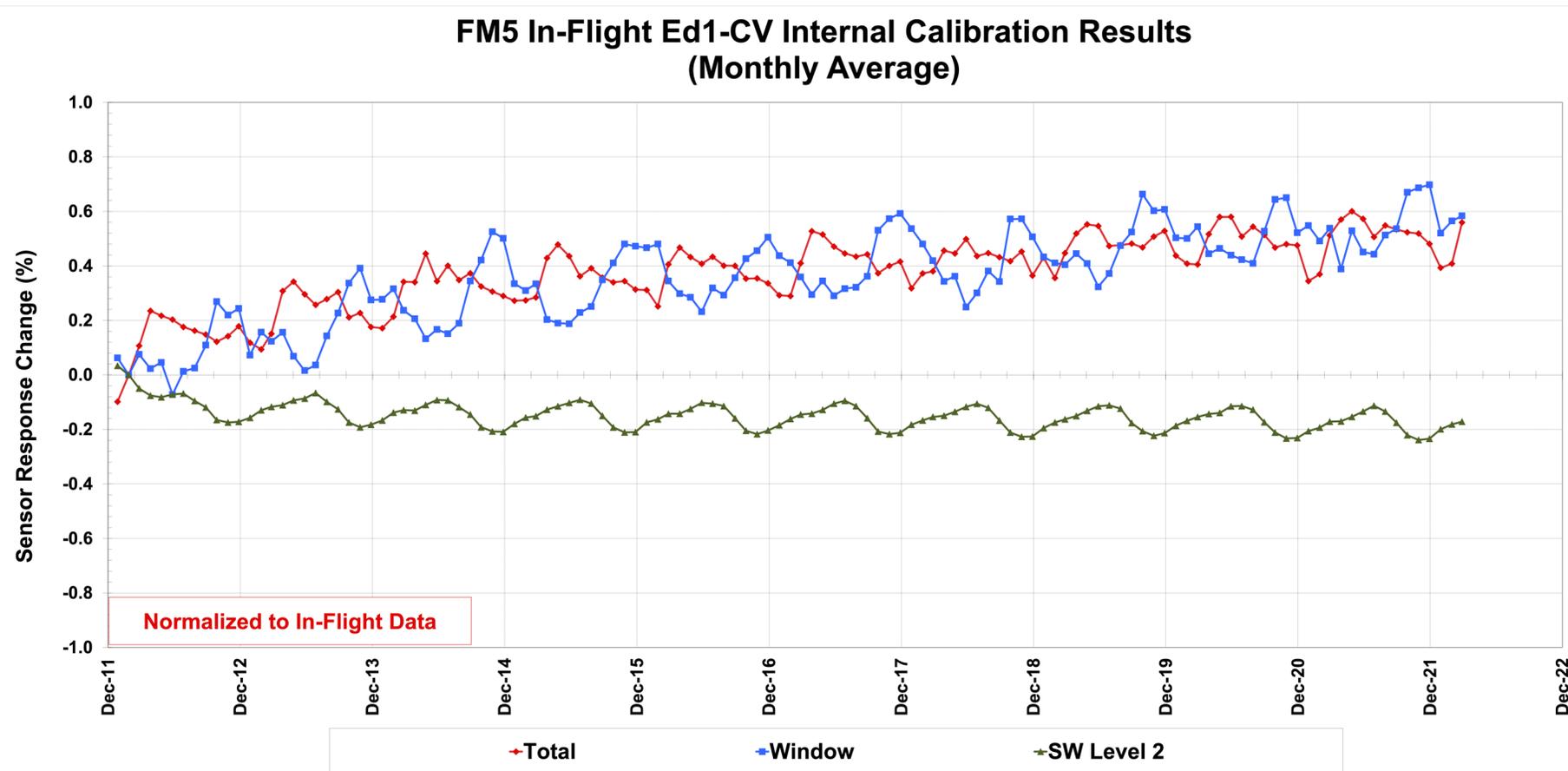
CERES Instrument Working Group



FM5 Internal Calibration

In response to the blackbodies, the FM5 TOT and WN sensors show a $\sim 0.6\%$ rise since start of mission.

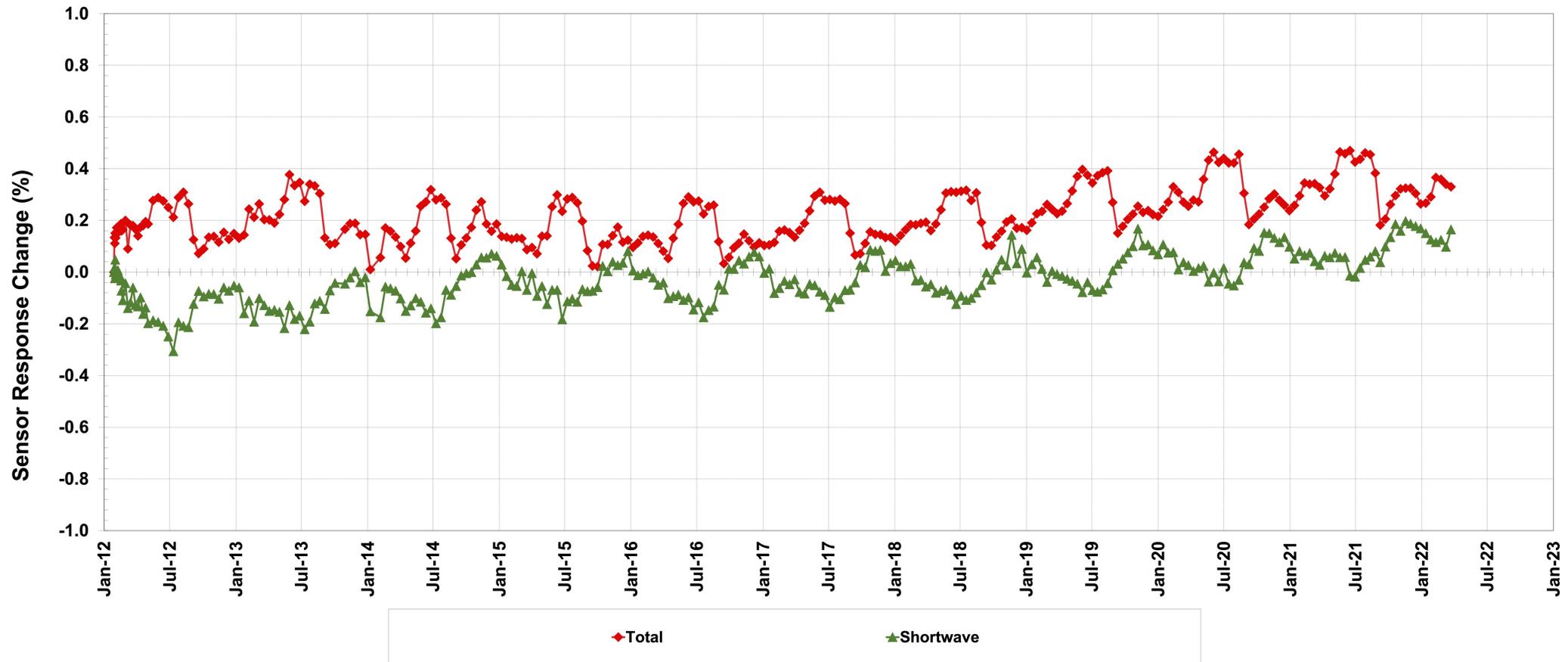
SW channel's response to the SWICS is stable at $\sim -0.2\%$ since start of mission.



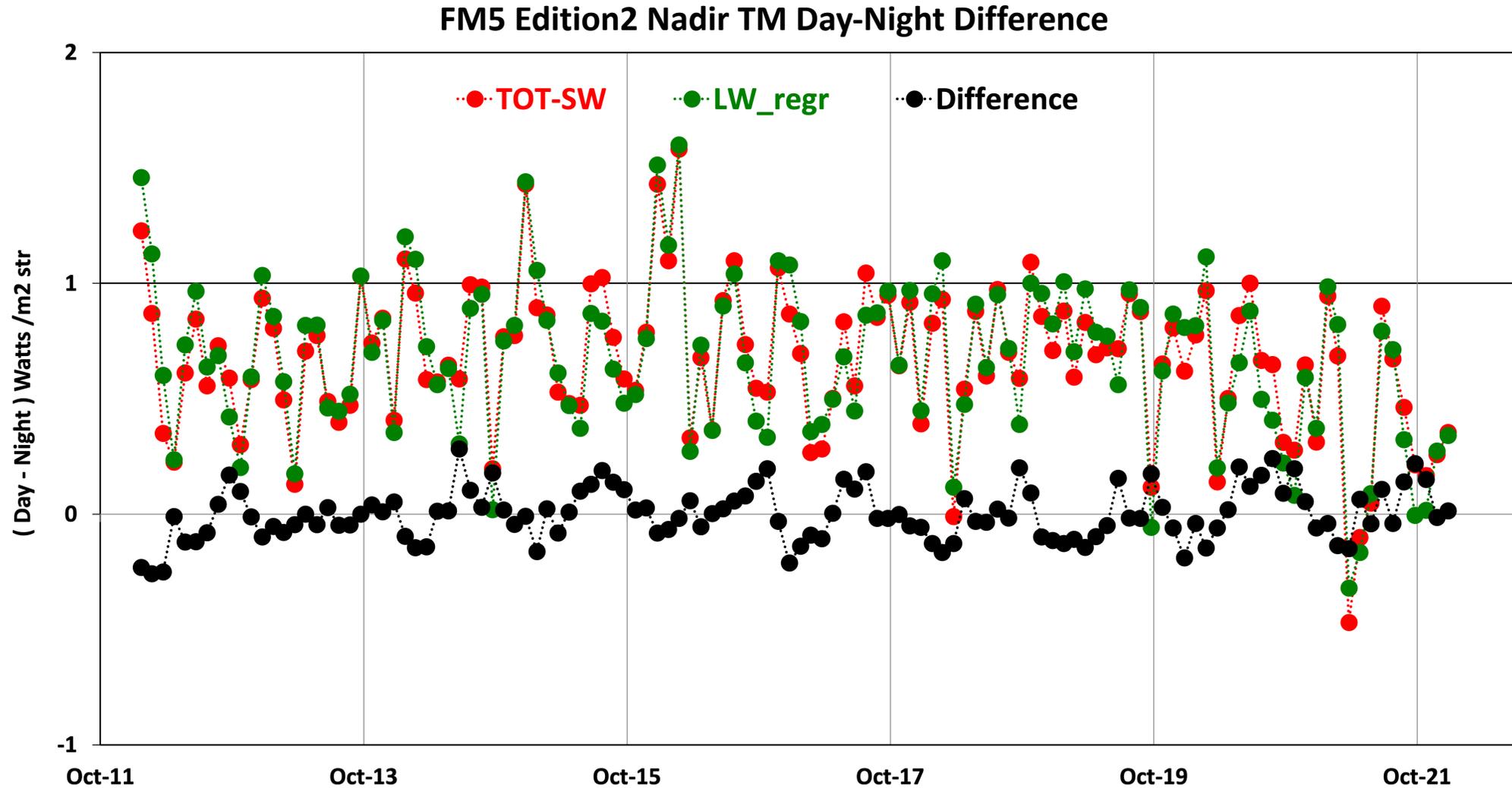
FM5 Solar Calibration

- FM5 Solar calibration results show the MAMs are very stable.
- TOT and SW responses show a slight upward trend in latter part of mission.

FM5 Solar Calibration



Validation- FM5 Tropical Mean

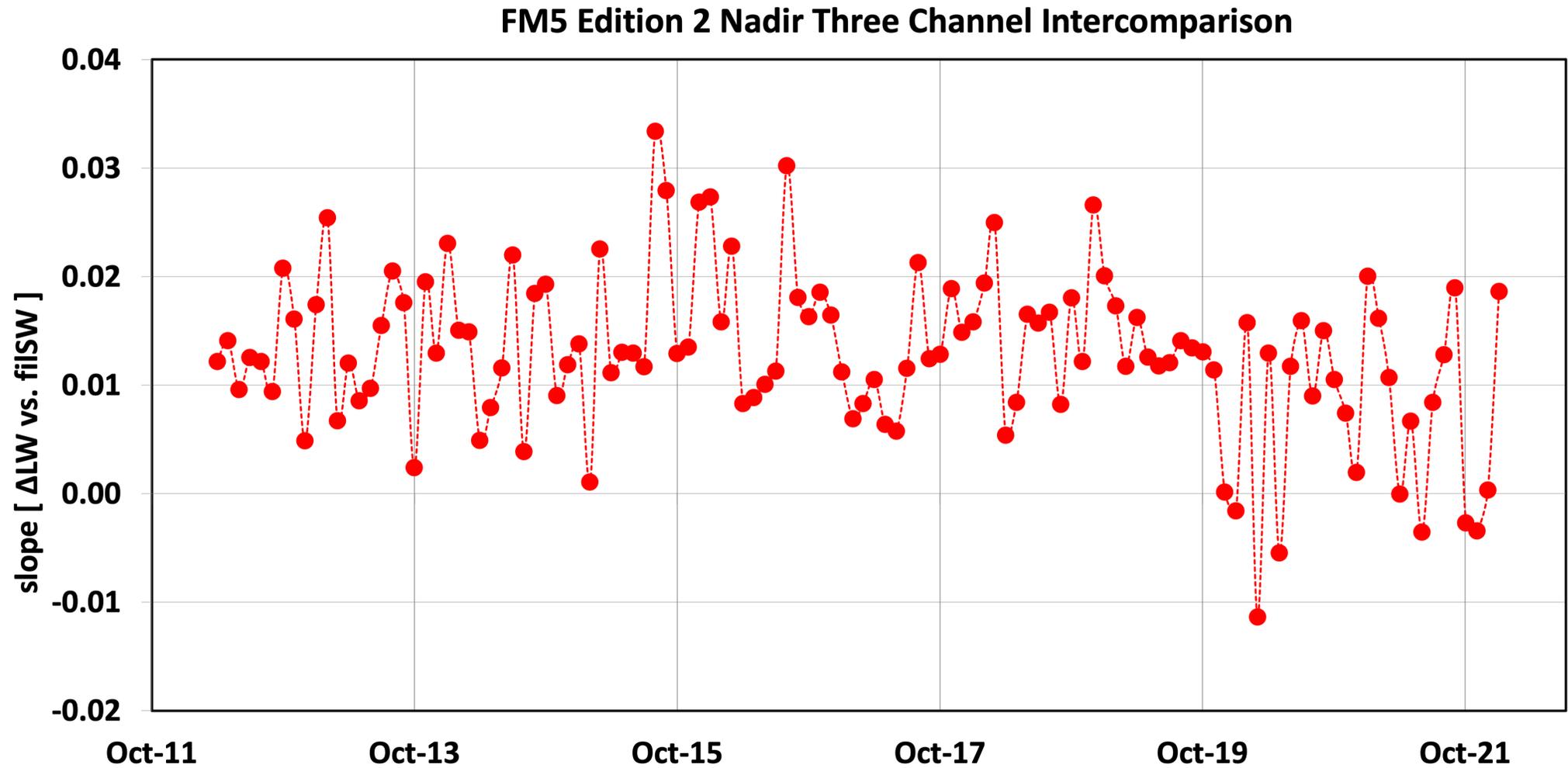


Validation: DCC 3-Channel Inter-comparison

- Compare the radiances from the three sensors of the instrument when viewing Deep Convective Clouds (DCC).
- Two sets of longwave (LW) radiances obtained:
 - TOT and SW sensors
 - Trained WN sensor
- Monitor the trend between the difference of the two LW radiances in relation to the SW radiance.
- Highlights any inconsistencies in the SW sensor or the shortwave part of the TOT sensor.

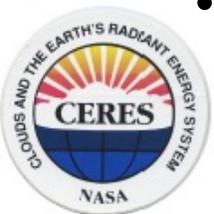


FM5 DCC 3-Channel Intercomparison



Aqua/S-NPP Intercomparisons

- The orbital geometries for Aqua and S-NPP are such that orbital overlaps occur every ~ 64 hours.
- Obtain spatially and temporally matched observations during every crossover.
- No special operations conducted; FM5 continues operating in biaxial mode.
- Use matching criteria to subset the data:
 - SZA, VZA difference $< 2.0^\circ$
 - RAZ difference $< 5^\circ$
 - Distance between footprints < 7 km
- Obtain monthly all-sky SW reflectance and daytime LW radiance differences using the matched footprints.
- *Since FM5 is operating in biaxial mode, the number of matched footprints has drastically reduced.*

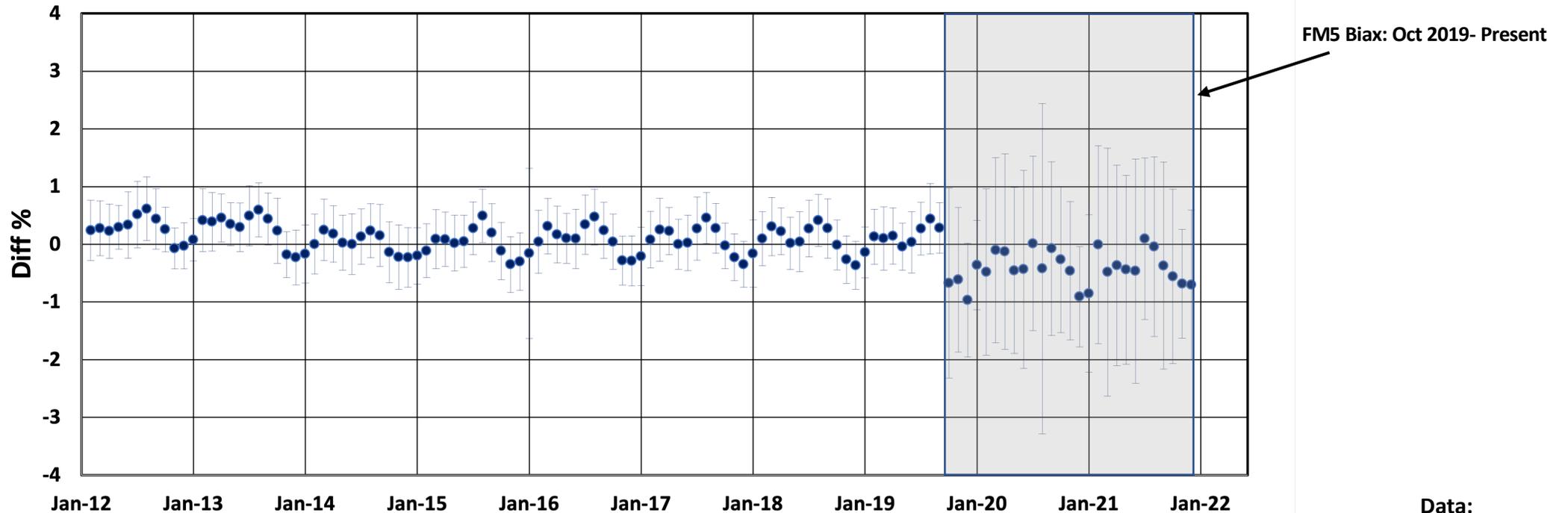


FM3/FM5 SW All-sky Inter-comparisons: Feb 2012- Dec 2021

Difference of Reflectance:
FM3-FM5 %, 95% CI

$$Reflectance = \frac{SW_{rad} * \pi}{F * \cos(SZA)} \quad F=1361 \text{ W/m}^2$$

Aqua (Ed4)/S-NPP (Ed2) SW Intercomparison



2014 data used for the radiometric scaling FM5 to FM3.

Data:

CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM5-VIIRS_Edition2A

Larger differences observed after FM5 switched to biaxial mode are driven by the drastic reduction in number of spatially and temporally matched observations.

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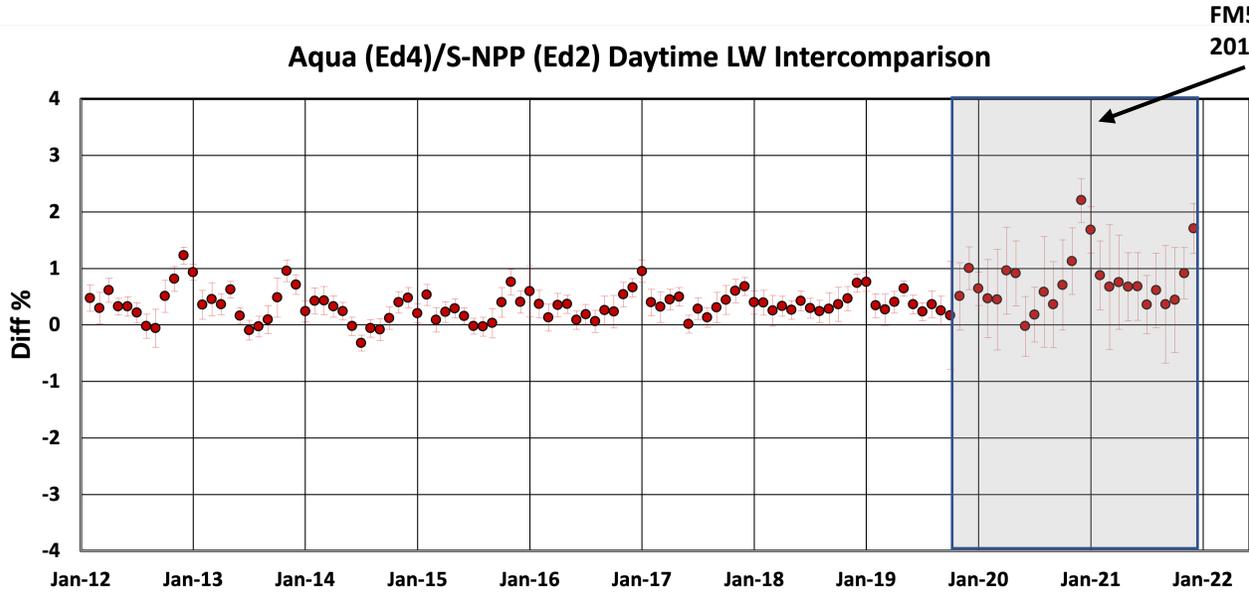


FM3/FM5 LW All-sky Inter-comparisons: Feb 2012- Dec 2021

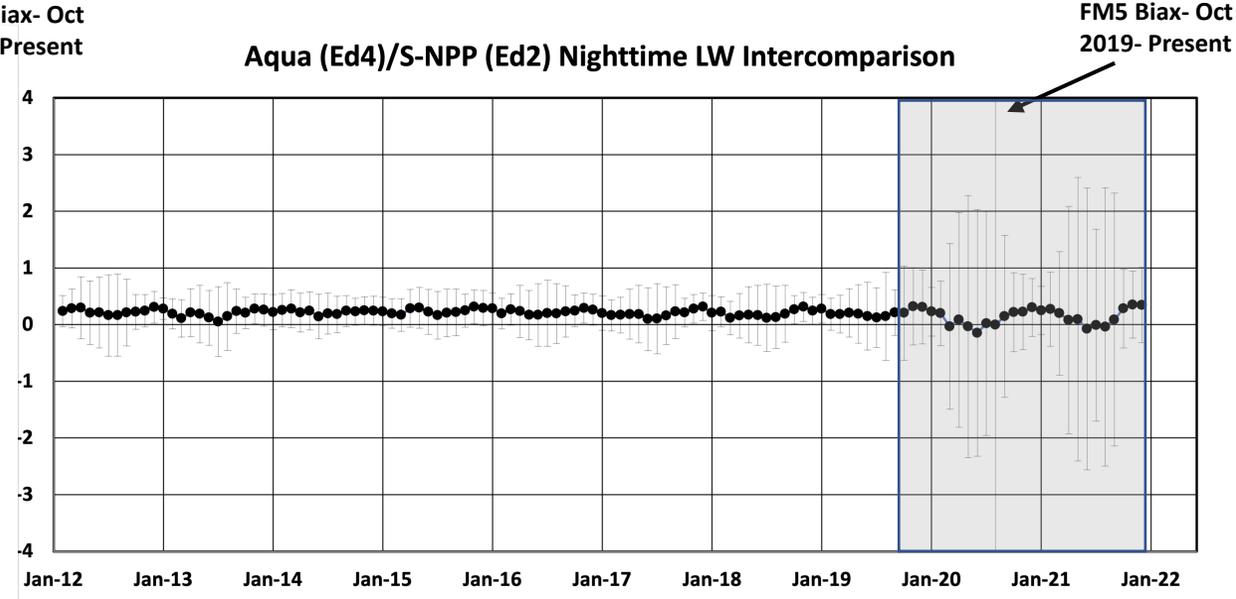
Difference of Daytime Radiance:
FM3-FM5 %, 95% CI

Difference of Nighttime Radiance:
FM3-FM5 %, 95% CI

Aqua (Ed4)/S-NPP (Ed2) Daytime LW Intercomparison



Aqua (Ed4)/S-NPP (Ed2) Nighttime LW Intercomparison



2014 data used for the radiometric scaling FM5 to FM3.

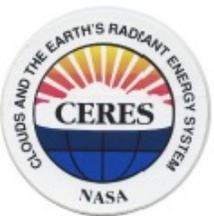
Data:
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM5-VIIRS_Edition2A

Larger differences observed after FM5 switched to biaxial mode are driven by the drastic reduction in number of spatially and temporally matched observations.

CERES Instrument Working Group

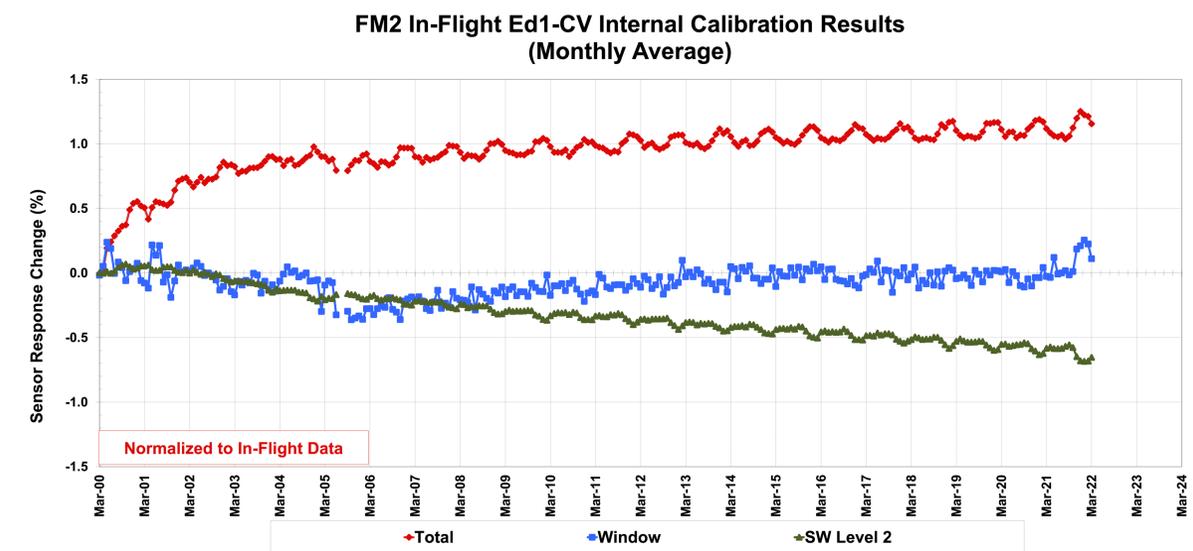
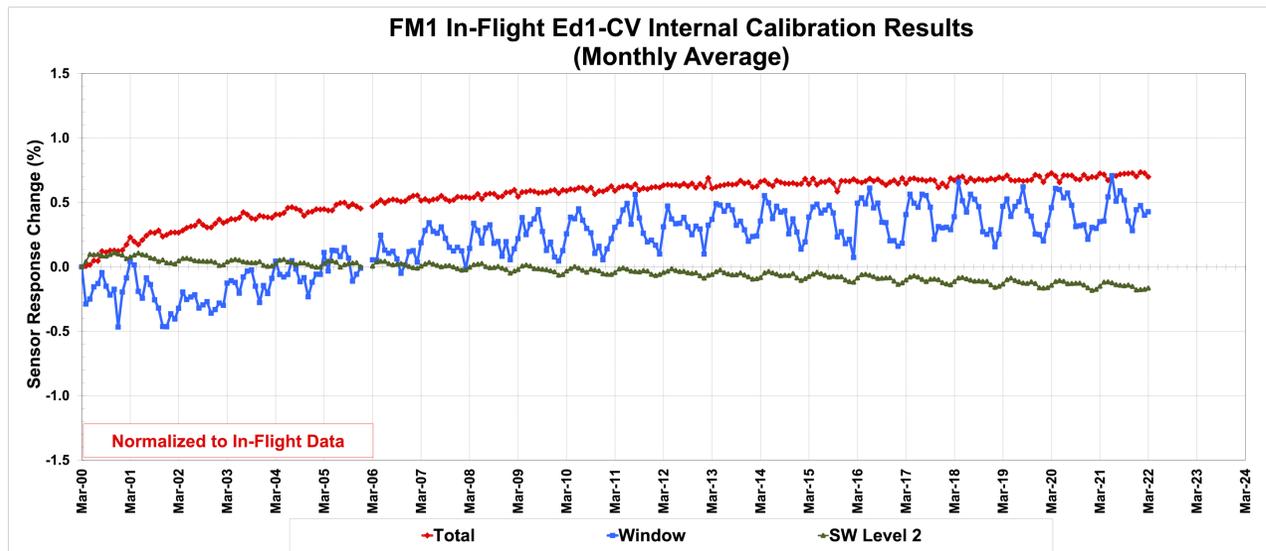


Terra & Aqua FM1-FM4 Instruments' Status



Terra- FM1 & FM2 Internal Calibration Results

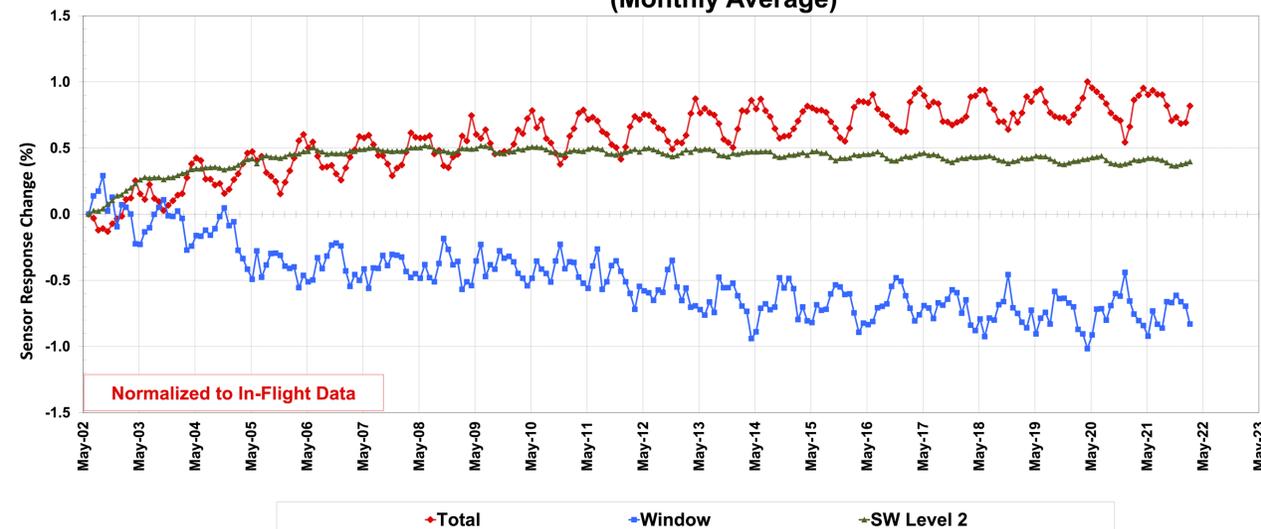
- For FM1, TOT channel shows $\sim 0.7\%$ rise, SW channel shows $\sim 0.1\%$ drop, and WN channel shows a rise of $\sim 0.4\%$ since start of mission.
- For FM2, TOT channel shows $\sim 1.2\%$ rise, SW channel shows $\sim 0.6\%$ drop, while WN channel shows $\sim 0\%$ change since start of mission.



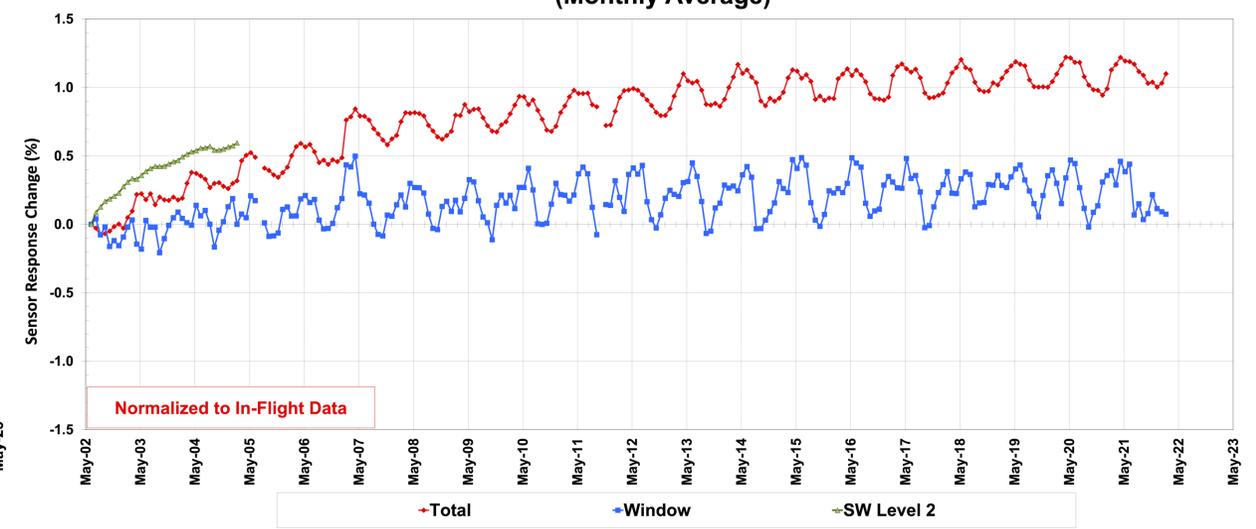
Aqua- FM3 and FM4 Internal Calibration Results

- For FM3, TOT channel shows $\sim 0.8\%$ rise, SW channel shows $\sim 0.4\%$ rise, and WN channel shows $\sim 0.8\%$ drop since start of mission.
- For FM4, TOT channel shows $\sim 1\%$ rise, while WN channel shows $\sim 0.25\%$ rise since start of mission.

FM3 In-Flight Ed1-CV Internal Calibration Results
(Monthly Average)



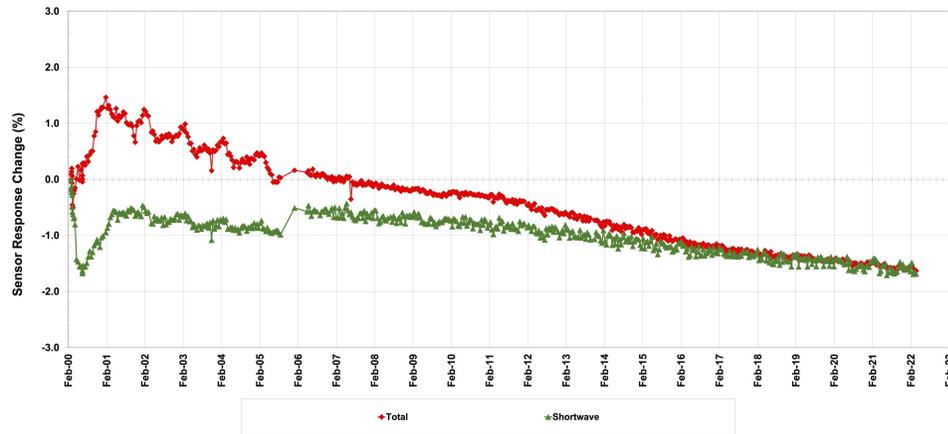
FM4 In-Flight Ed1-CV Internal Calibration Results
(Monthly Average)



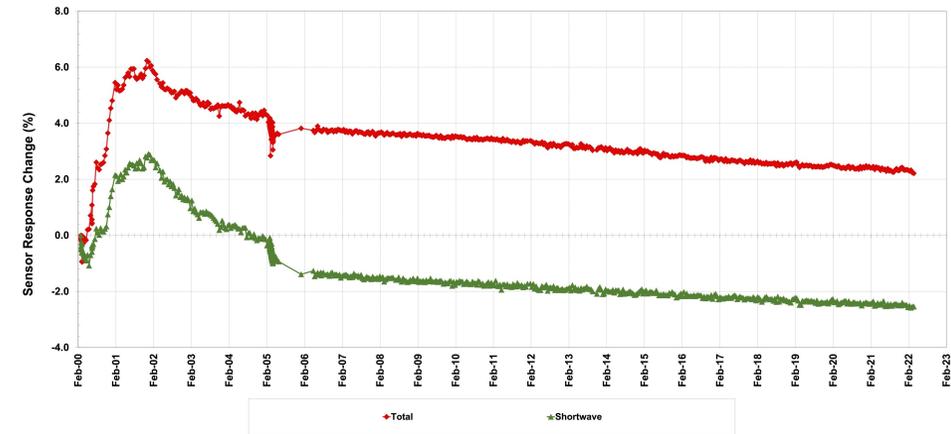
Terra & Aqua Solar Calibration

Since the start of raster scan for solar calibration, SW channel data shows a drop of response of ~1% and TOT channel shows a drop of 1.5%-2% for all instruments.

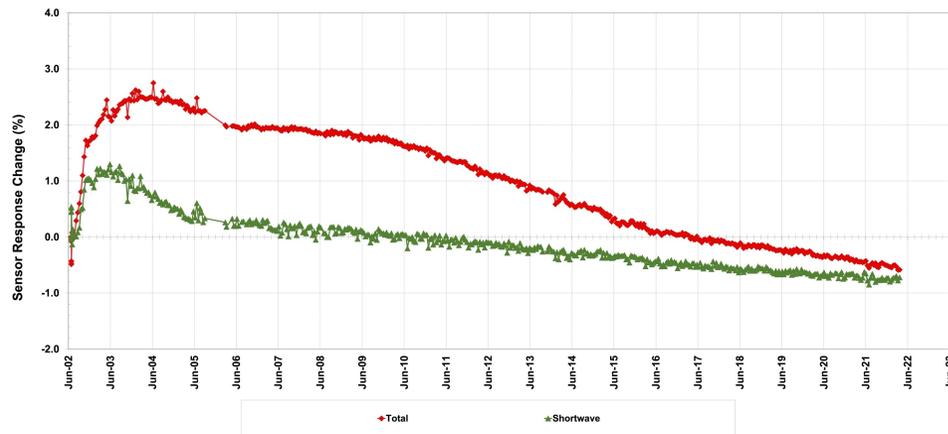
FM1 Solar Calibration



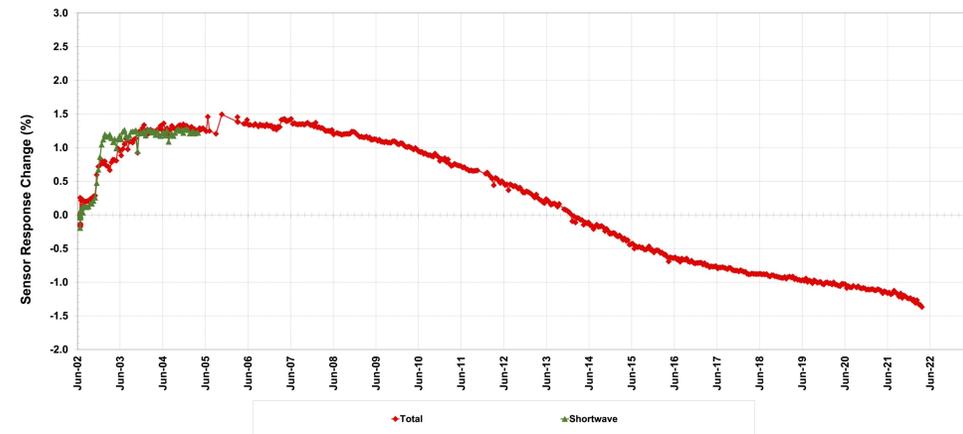
FM2 Solar Calibration



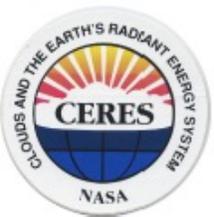
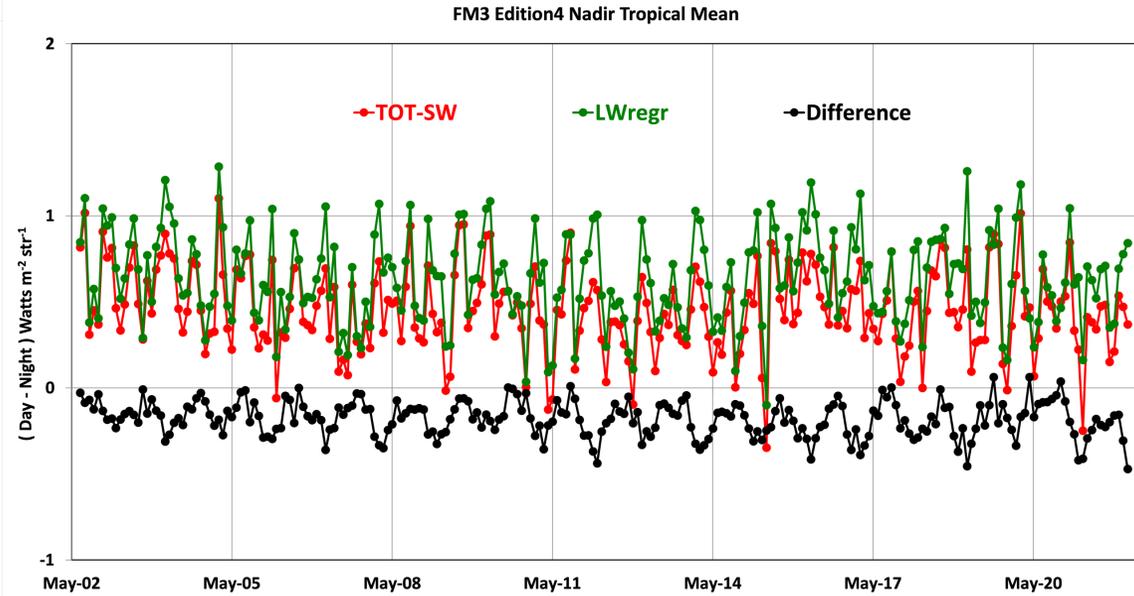
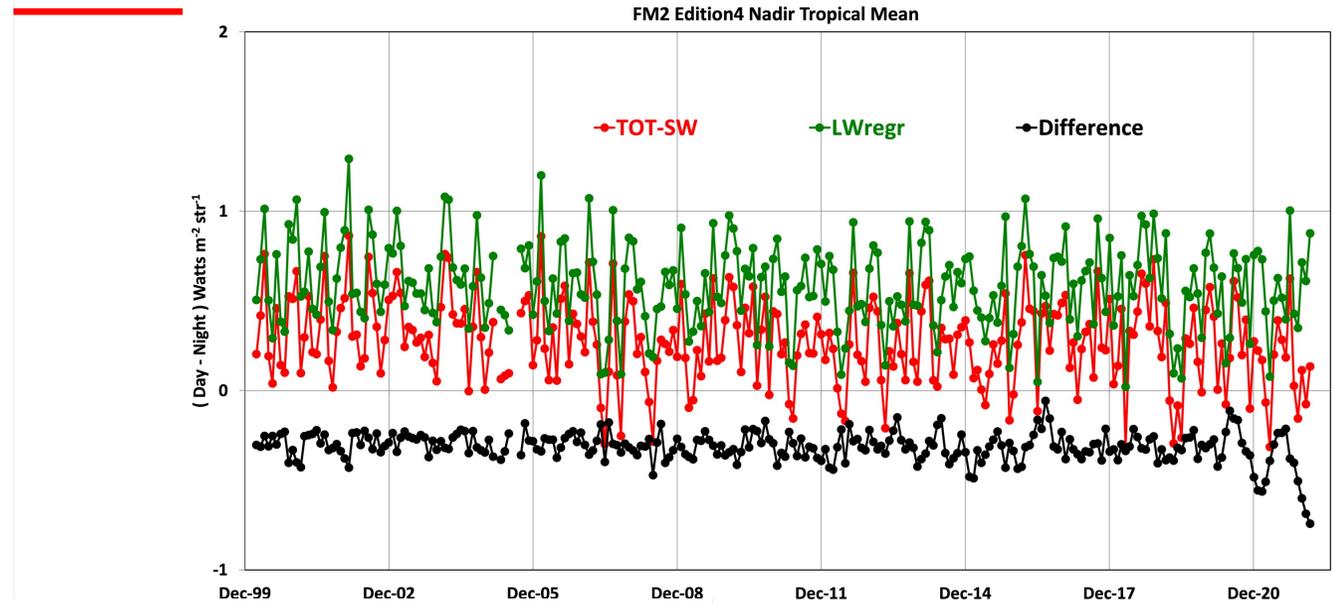
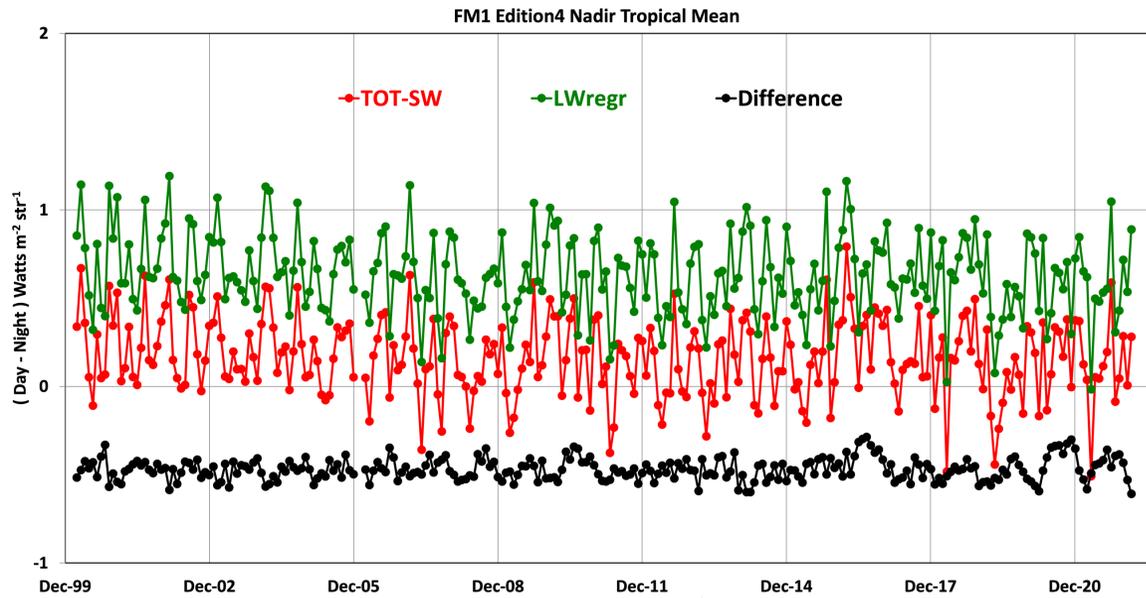
FM3 Solar Calibration



FM4 Solar Calibration

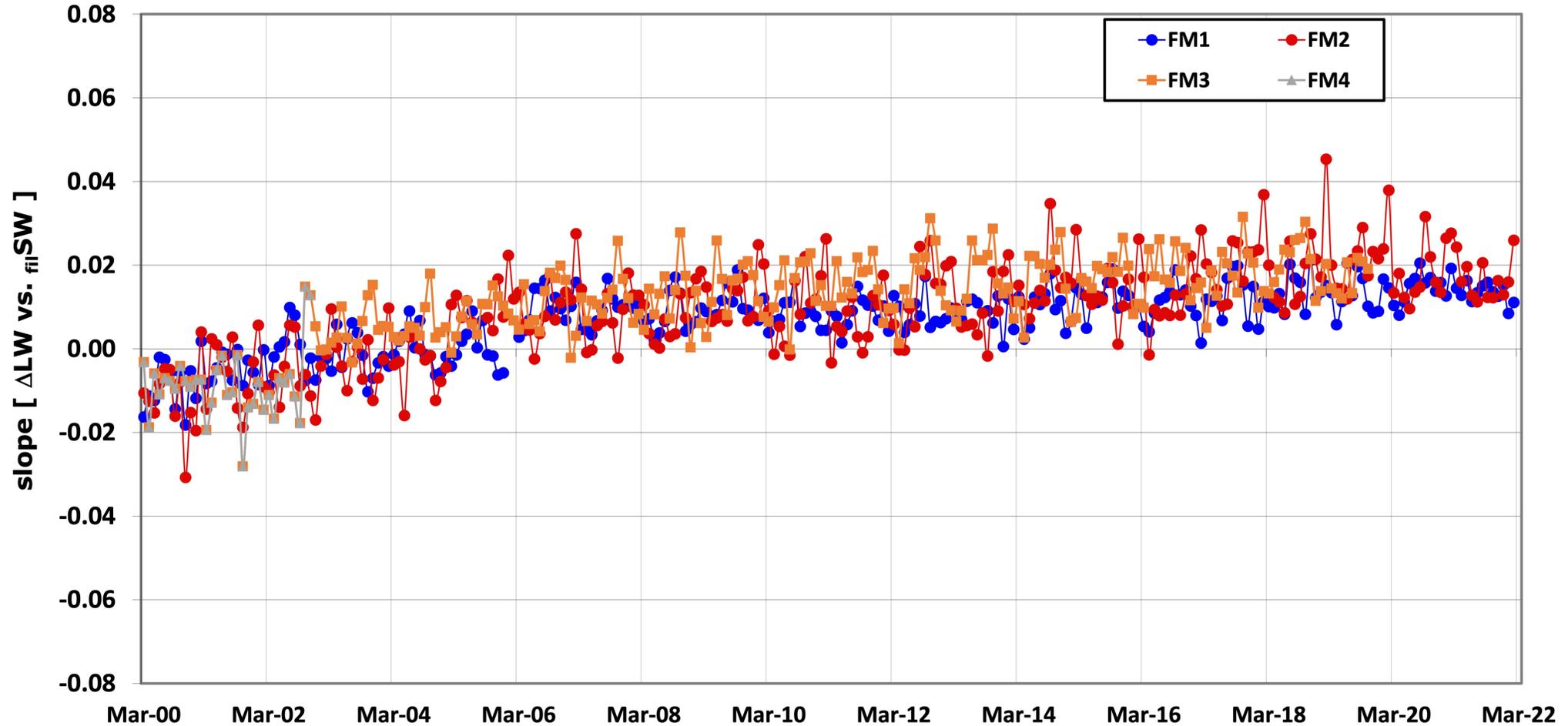


Validation- Terra and Aqua Tropical Mean



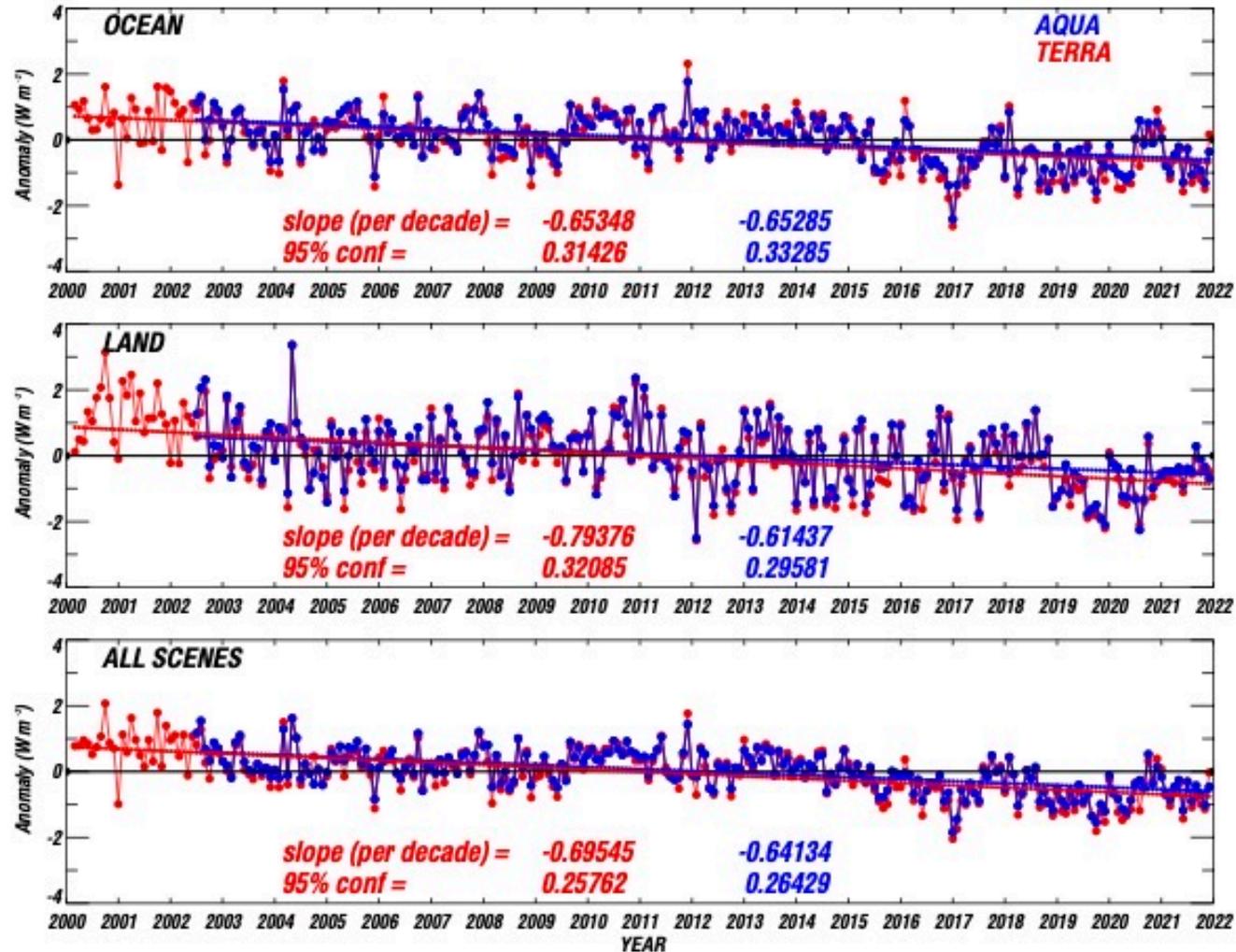
Validation- DCC 3-Channel Intercomparison

Edition 4 Terra and Aqua Nadir Three Channel Intercomparison



Validation: Terra and Aqua Ed-4 SW Flux Anomalies

Anomaly of Terra and Aqua SW Flux (SSF1deg) for All Sky Scenes

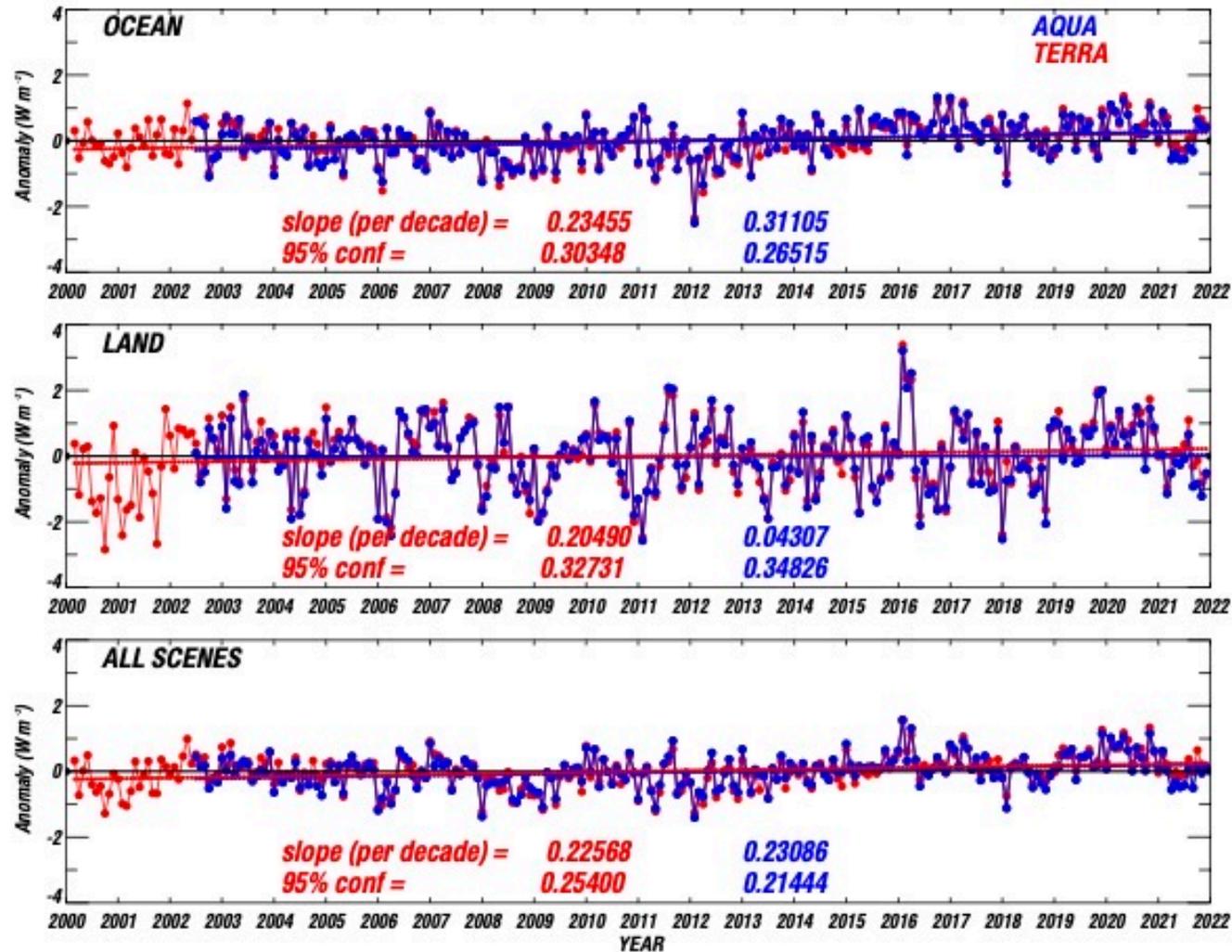


SW flux anomalies show similar trends for Terra and Aqua



Validation: Terra and Aqua Ed-4 LW Flux Anomalies

Anomaly of Terra and Aqua LW Flux (SSF1deg) for All Sky Scenes



LW flux anomalies show similar trends for Terra and Aqua.



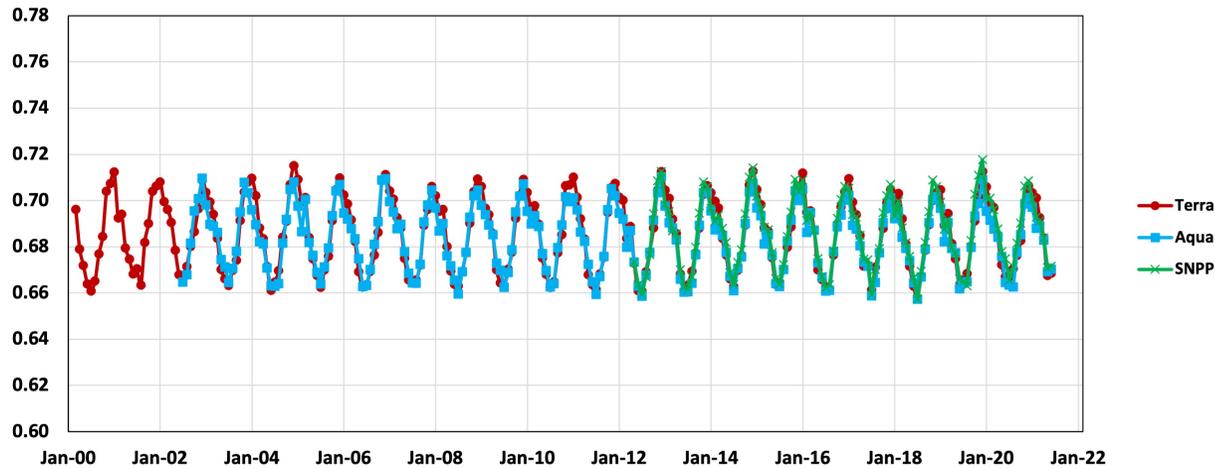
Validation: DCC Albedo

- Observe the long-term trends of DCC albedo.
 - Uses Level-2 products (SSF), calculate monthly means of DCC footprints.
 - Trend the DCC albedos for instruments on Terra, Aqua, S-NPP.
- For Terra and Aqua, consider data from instruments operating in cross-track mode.
- Criteria for selecting DCC:
 - Consider all footprints with VZA, SZA < 40 deg.
 - Latitude bands: 30⁰ N-S, Over Ocean.
 - Cloud Fraction= 100%.
 - Use MODIS/VIIRS 11um channel to identify footprints with brightness temperature <210K.
 - WN channel filtered radiance < 1 Wm⁻²sr⁻¹um⁻¹ .



Validation: DCC Albedo

DCC Albedo



Data Series:

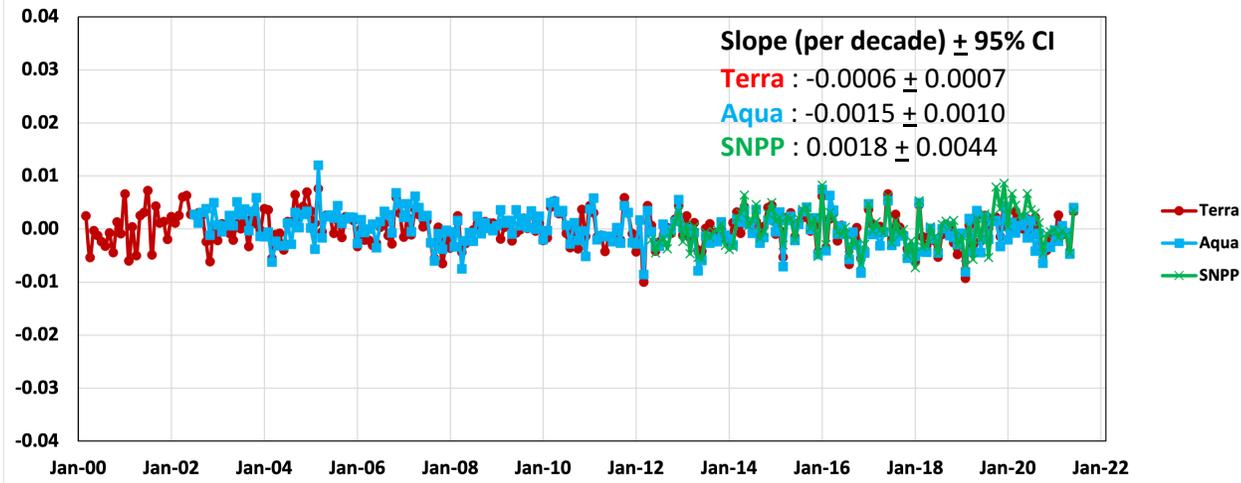
Terra: Mar 2000- Jun 2021

Aqua: Jul 2002- Jun 2021

SNPP: May 2012- Jun 2021

DCC trends show that CERES instruments on Terra, Aqua and SNPP are very consistent with each other, with no significant long-term trends.

DCC Albedo Anomaly



Slope (per decade) \pm 95% CI

Aqua-Terra: -0.0007 ± 0.0012

SNPP-Terra: 0.0025 ± 0.0028

SNPP-Aqua: 0.0034 ± 0.0028

Data:

- CER_SSF_Terra-FM1-MODIS_Edition4A
- CER_SSF_Terra-FM2-MODIS_Edition4A
- CER_SSF_Aqua-FM3-MODIS_Edition4A
- CER_SSF_Aqua-FM4-MODIS_Edition4A
- CER_SSF_NOAA20-FM5-VIIRS_Edition2A



SUMMARY

- **All CERES instruments continue to perform nominally.**
 - NOAA-20/FM6 instrument on-board calibrations continue to show the sensors' stable performance after the initial response rise.
 - SNPP/FM5 is currently operating in full biaxial mode, collecting ADM data.
 - *No evidence of deviation of instrument performance since transitioning to biaxial mode.*
 - Validations show that all instruments are performing consistently.
 - *Validation using long-term DCC albedos : FM1-FM5 show consistent and stable performance.*
- **Data products**
 - NOAA-20/FM6 Edition 1 gains have been finalized and delivered through Mar 2022.
 - S-NPP/FM5 Edition 2 gains and SRFs have been delivered through Mar 2022.
 - Terra and Aqua instruments' Edition 4 gains and SRFs have been delivered through Feb 2022.
- **Members of the IWG continue to engage with the Libera team through bi-weekly Cal/Val Working group meetings.**



Backup



CERES Instrument Working Group



Instrument Product-line definitions

- **NOAA-20**

- *Edition1-CV*: Products without any on-orbit instrument calibration corrections applied.
- *Edition 1*: Incorporates the most up-to-date calibration corrections, radiometric scaling to Aqua.

- **S-NPP:**

- *Edition 1-CV*: Products without any on-orbit instrument calibration corrections applied.
- *Edition 2*: Incorporates the most up-to-date calibration corrections, radiometric scaling to Aqua, and time varying SRF adjustments to TOT channel.

- **Terra/Aqua:**

- *Edition 1-CV*: Products without any on-orbit instrument calibration corrections applied.
- *Edition 4*: Incorporates the most up-to-date calibration corrections, radiometric scaling and time varying SRF adjustments to SW and TOT channels.

